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Investigation of engineering characteristics of calcareous soils from fringing reef

Xin-Zhi Wang[a,*], Xing Wang[a,b], Zong-Chuan Jin[c], Chang-Qi Zhu[a], Ren Wang[a], Qing-shan Meng[a]

[a] State Key Laboratory of Geomechanics and Geotechnical Engineering, Institute of Rock and Soil Mechanics, Chinese Academy of Sciences, Wuhan 430071, China
[b] University of Chinese Academy of Sciences, Beijing 100049, China
[c] Shanghai Geotechnical Investigations & Design Institute Co., Ltd., Shanghai 200032, China

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ABSTRACT

Engineering characteristics of calcareous soils are more peculiar due to the grain geometries, hardness and intraparticle voids. In the fringing reef in Sanya, calcareous soils were mixed with some terrestrial deposits, such as quartz sand and clay. In this paper, a series of laboratory and in-situ tests are conducted on calcareous soils to investigate the engineering characteristics and the effect of water saturation: laboratory large-scale direct shear tests, large-scale oedometer tests, X-Ray diffraction experiments, in-situ Plate Load Tests (PLTs) and Dynamic Cone Penetration Tests (DCPTs). The results showed that: (i) apparent cohesion of calcareous soils is quite higher than that of quartz sand but decreases significantly due to the softening effect of water; (ii) the bearing capacity decreases by 43% and deformation modulus decreases by 31% at the presence of 20% clay minerals; (iii) deformation modulus reduces 80% in saturated condition compared to dry condition; (iv) the relationship between $N_{63.5}$ and bearing capacity of calcareous soils was established; therefore, engineers can decrease the amount of PLTs and increase DCPTs in the site exploration of fringing coral reef according to the testing results.

1. Introduction

Recently, with the increasing of ocean engineering activities, there is an obvious hotspot in the understanding about engineering behavior of coral reef sediments (Poulos, 1990). Calcareous soils have been served as building foundation in oceanic engineering recently, and researchers (Maksoud, 2006; Shahnazari and Rezvani, 2013; Sharma et al., 2004) have started to pay more attentions to its mechanical properties. Alba and Audibert (1999) reported that the mechanical characteristics and behavior of calcareous soils were highly dependent on the original sedimentary environment. The character of biogenic calcareous sands is quite different from that of quartz sands, yet our understanding of the behavior of granular soils comes primarily from studies conducted on quartz sands of terrigenous origin. Calcareous soils typically have lower grain hardness, larger intragranular porosity, a wider range of grain shapes, and more complex structural arrangements that reflect unique post-depositional processes of cementation, dissolution, recrystallization, and other diagenetic changes (Brandes, 2011). It is not surprising that there are significant differences in mechanical behavior among various types of calcareous sands, and with respect to quartz sands (Celestino and Mitchell, 1983).

Calcareous soils are widely distributed in the Nansha Islands, South China Sea and also common on the coast of Sanya, a southern city in China. Calcareous soils found in the Nansha Islands are mainly composed of calcium carbonate, which exceeds 97% by weight (Wang et al., 2011). However, in Sanya the calcareous sediments in fringing reefs contain plentiful continental deposits such as quartz sand and clay. These continental sediments changed the engineering behavior of calcareous soils due to the effect of water saturation. Therefore, the engineering characteristics of calcareous soils deposited in fringing reefs are quite different from the Nansha Islands. In order to investigate the engineering characteristics and the effect of water saturation on calcareous soils derived from the fringing reef in Sanya, a series of laboratory and in-situ tests, consisting of laboratory large-scale direct shear tests, large-scale odoemeter tests, in-situ Plate Load Tests (PLTs) and Dynamic Cone Penetration Tests (DCPTs) have been conducted. Moreover, another objects of this study was to investigate the relationship between DCPT blow count and bearing capacity. The test results will give a preliminary understanding about calcareous soils in fringing reef. The test results and viewpoints also give some references to bulwark-seabed interaction modelling on calcareous soils from fringing reef (Ye et al., 2016a, 2016b).

* Corresponding author.
E-mail address: xzwang@whrsm.ac.cn (X.-Z. Wang).

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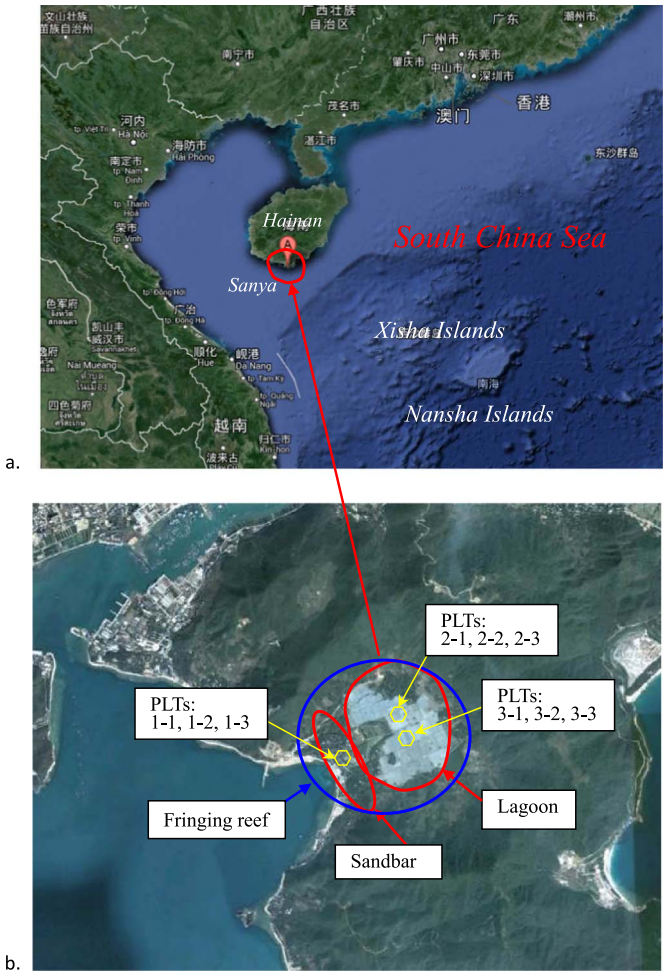

Fig. 1. Location of experiment site (Fringing reef, Sanya).

2. Description of site and geological conditions

The experimental site is located on a fringing reef at the coast of Sanya city, Hainan province (Fig. 1a). The fringing reef has a typical open lagoon geomorphology as shown in Fig. 1b. The lagoon is surrounded by mountains on three sides and is close to the sea.

The coral reef, originally formed at the end of the last glacial period, began to rise sluggishly with the rising sea level about 10,000 years ago. As some valleys close to the sea became shallow bays which were suitable for coral growth, coastal coral reefs gradually developed with the rising of sea level. Since the Holocene, the sea level was 4–8 m higher than now and began to decline to the current level (Gvirtzman et al., 1992; Kershaw et al., 2003). As the sea dropped the calcification of corals happened and the sediments crushed by currents and waves. The coral fragments mixed with some terrestrial soils (such as quartz sand and clay) deposited in the valleys, which developed as the lagoons in fringing reef (Yu et al., 2004). The thickness of the deposition in the lagoon is about 8–10 m and the area of fringing reef is approximately 5 km^2.

The fringing reef are composed of two typical sedimentary land-forms-sand bar and lagoon shown in Fig. 1b. The stratigraphic profile of the sand bar was shown in Fig. 2. The dominating sediments are comprised of calcareous sand and coarse gravels that originated from shell fragments and skeletal debris of madrepore. The groundwater table is 2.5 m below the ground measured from boreholes. The in-situ PLTs of group 1# (test numbers 1-1, 1-2 and 1-3) were conducted in this stratum at the depth of 1.7 m (Figs. 1 and 2), which was above the groundwater table.

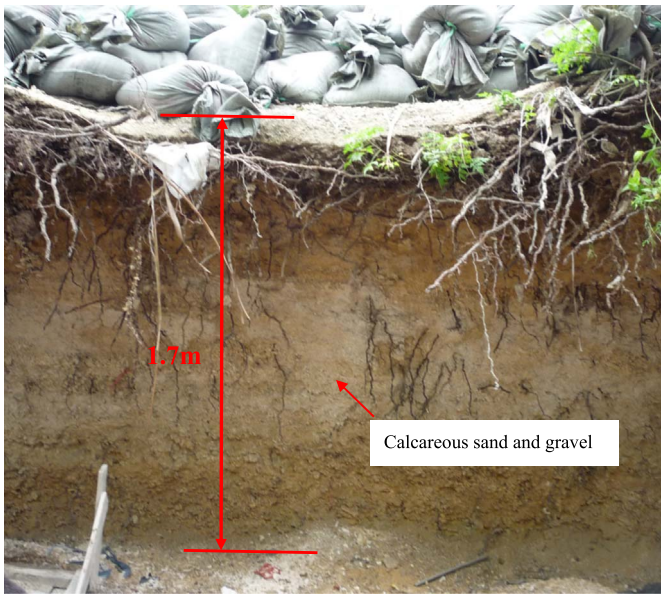

Fig. 2. Stratum profile of test GROUP 1# (at a depth of 1.7 m).

Fig. 3. (a) Geological profile of test GROUPs 2# and 3#; (b) Lagoon soil (clayed sand with gravel, mixed with terrestrial deposits).

The lagoon, in the center of coral reef, is surrounded by rolling hills. Calcareous soils in the lagoon were mixed with terrestrial deposits (Fig. 3) washed from the hillside. The scanning electron microscope of soil particles is shown in Fig. 4. The particles are quite angular and contain intraparticle voids. Fig. 5 shows a geological columnar section of the lagoon stratum derived from drilling. The groundwater lever of